

PERFORMANCE OF POWER TILLER WITH DIFFERENT CAGEWHEELS IN WET LAND

PIYUSH PRADHAN¹, AJAY VERMA², KIPOO KIRAN³ & RAGESH KT⁴

¹Research Scholar, Department of Farm Machinery and Power Engineering, Faculty of Agricultural Engineering, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

²Professor, Department of Farm Machinery and Power Engineering, Faculty of Agricultural Engineering, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

^{3,4}Research Scholar, Department of Farm Machinery and Power Engineering, Faculty of Agricultural Engineering, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

ABSTRACT

To evaluate the performance power tiller for different angle and diameter of cage wheel was tested in the inceptisol at 0-5 cm, 5-10 cm, 10-15 cm and 15-20 cm, depth of water level. The cage wheel 73 cm diameter with 30°, 45°, and 60° lug angle and different diameter of 68 cm, 73 cm and 78 cm of 30° lug angle of cage wheel, was tested in four water levels of 5, 10, 15 and 20 cm in wet land field. The better result was found in cage wheel C1 of 30° lug angle with 73 cm diameter give better performance than other cage wheel. The cage wheel showed the best result in 15 cm water level in respect to minimum time requirement for puddling operation 8.69 h/ha, maximum working speed 1.82 kmph, actual field capacity 0.118 ha/h with 85.73 % field efficiency, less fuel consumption 9.39 l/ha, minimum slippage 10.41 %, with maximum puddling index of 29.25 % and less sinkage 2.33 cm on lug surface.

KEYWORDS: Time of Operation, Actual Field Capacity, Field Efficiency, Slippage, Sinkage, Puddling Index

INTRODUCTION

Power tiller is walking tractor mostly used for rotary cultivation in puddle soil. Cage wheel have proved one of the important traction devices for wet land cultivation. Physical conditions of the soil in poorly drained paddy fields were also defined to distinguish it from the general wetlands. The efficiency with which a Power tiller converts energy into pull is extremely poor when operating on wet soil. The top layer of wet soil has low shear strength so that sufficient thrust cannot be developed. Besides the slipperiness, stickiness and sinkage limit the available pull and forward speed of a power tiller. In such situations the middle layer of the soil bears the traffic load of agricultural machinery. The initial introduction of power tillers was without a complete range of matching equipment (Kathirvel *et al.* 2000). Power tiller having limitations in their use for traction work due to the low drawbar power per brake horsepower of the engine. At present, most of the power tiller manufactured in the country are in the range of 8-10 hp and weigh about 400 kg. The power tillers are not potentially used in hilly areas due to the lack of its manoeuvrability on sloppy lands. In wet fields, with a hard pan at considerable depth, the utility of agricultural machines is limited due to their bogging down in the soil. In agricultural operations, the effect of the vehicle on the soil is more important than the maximum traction that can be developed.

A tractor that develops the desired pull at high efficiency may not be useful if it makes ruts in the soil so severe that subsequent cultural operations are adversely affected. Traction problems in the saturated paddy soils have a major limitation to the adaptation of agricultural mechanization in rice producing Asian countries. Sinkage of agricultural machinery has been the topic of intensive research in the past and will continue to be in the future. The main problem in mechanizing paddy cultivation is the development of a suitable traction device for operation in the saturated soils. Soft soils with low trafficability have resulted in excessive sinkage of agricultural machinery (Abubakar *et al*). Maintenance of the power tiller is set of simple compulsory operations specified in the relevant documents, which if carried out properly will keep the machine available throughout the service life (Gupta and Sinha, 2000). Considerable time and energy are lost in attempting to cultivate in soft soils. Because of the extra time necessary to remove sunken machinery from the fields.

MATERIALS AND METHODS

The Indian made and model power-tiller VST SHAKTI 130 DI is a single-axle (two-wheel) tractor with 10 kW (13 hp) rated power, diesel engine of 2400 rpm rated crankshaft speed. The engine is single cylinder horizontal 4 strokes, water cooled and hand cranking type. The driving wheels were different angle, 30°, 45°, 60° of C1, C2, and C3 and diameter, C1 73 cm, C4 68 cm, C5 78 cm of the steel or cage wheel used for wet puddling operation. The field performance evaluation of the model was carried out in different water level, 5 cm, 10 cm, 15 cm and 20 cm replication of as R1, R2, R3 and R4 in IGKV research field Raipur on a sandy loam soil. Studies shows that Alvi and Pandya (2001) have conducted trials to test a 7.46 kW power tiller for drawbar pull, fuel consumption and wheel slip. At 18% wheel slip, the drawbar power and specific fuel consumption were 1.38 kW and 1.62 kg/dbkWh, respectively. Iron wheels equipped on walking tractors are more economical than high-lug tires (Gupta and Kumar, 2001).

Width of 750 mm tine cultivator was attached to the power tiller. The data collection process covered parameters such as Average time of operation (h/ha), Actual field capacity (ha/h), Theoretical field capacity (ha/h), Field efficiency (%), Working speed (km/h), Fuel consumption (l/ha), Fuel consumption (l/h), and Slippage (%). The data collected were summarized and subjected to One-way analysis of variance to compare the performance in the four locations.



Figure 1: Different Types of Cage Wheel Used in Wet Land

A great many vehicles which have to work in flooded, puddle soils use cage wheels. These have been found, in practice, to be greatly superior to rubber tyre in this environment (Datta and Ojha). Experiments were carried out by Jayasundera to investigate this phenomenon and also the effect of lug angle on wheel forces. He used a small (11 kW) four-wheel (two wheel drive) tractor in these experiments. The results showed that initially, as the number of lugs was

Increased from 6 to 9 to 12 there was a continuous increase in power transmitted. As the number was increased from 12 to 18, however, there was a rapid decrease. The best combination was found to be 12 lugs at a 30 degree lug angle.

Effective field capacity

$$C = A / T_p + T_t$$

Where

C = Effective field capacity (ha/h)

A = Area covered (ha)

T_p = Productive time (h)

T_t = Non –Productive time (h)

$$\text{Theoretical field capacity (ha/h)} = \frac{\text{Speed (km/h)} \times \text{Width of implement (m)}}{10}$$

$$\text{Field efficiency (\%)} = \frac{\text{Effective field capacity}}{\text{Theoretical field capacity}} \times 100$$

$$\text{Puddling Index} = V_s / V \times 100$$

Where

V_s = volume of settled soil, a

V = total volume of sample

RESULTS AND DISCUSSIONS

The experimental unit was fabricated in the work shop of the Faculty of Agricultural Engineering and the performance of the cage wheels in wet land condition, was observed in the actual field condition, with different water level, during 2014-15, in medium field condition with sandy loam soil. The treatments consisting of different angle and diameter of cage wheels were randomly laid out and replicated as per statistical design. Different types of observations were recorded, statistically analyzed and presented under following heads.

Different Lug Angle of Cage Wheel

Time of Operation

The angle of 30°, 45°, and 60° of cage wheel was operated in 0-5 cm, 5-10 cm, 10-15 cm and 15-20 water levels with five times of cultivator. It was observed that minimum lug angle giving higher performance with lower time consuming while as lug angle increases time of operation increases. It was also observed that when the water level increases time of operation decreases in all cage wheels. Time of operation at different treatment was given in (Table 1) which shows the minimum time required per hectare in cage wheel C1 followed by C2 and C3.

Table 1: Time of Operation (H/Ha) at Different Lug Angle of Cage Wheel

Treatment/Replication	R1	R2	R3	R4	Mean
C1	9.80	7.94	6.94	10.10	8.69
C2	10.20	8.93	7.35	10.86	9.33
C3	10.75	9.43	7.93	12.19	10.07

Working Speed

The working speed of power tiller in wet land condition was reduced during increasing of lug angle of cage wheel. It was also observed that as increasing in water level, the working speed increases. The average working speed of cage wheel was found to be 1.82, 1.73 and 1.63 kmph for cage wheel C1,C2 and C3 respectively (Table 2).

Table 2: Working Speed at Different Lug Angle of Cage Wheel

Treatment/Replication	R1	R2	R3	R4	Mean
C1	1.64	1.86	2.23	1.58	1.82
C2	1.59	1.73	2.1	1.52	1.73
C3	1.46	1.68	1.97	1.42	1.63

Actual Field Capacity

The actual field capacity depends upon the working width of the implements and speed of operation. The working width depends on the number of tynes and spacing between two successive tynes. It is actual area covered per unit time in which includes turning losses, slippage, clogging. It was observed that as lug angle increases field capacity decreases. Table 3 given below shows the variation of field capacity with respect to different angle of cage wheels. Maximum field capacity was observed cage wheel C1 at R3 condition.

Table 3: Actual Field Capacity (Ha/H) at Different Lug Angle of Cage Wheel

Treatment/Replication	R1	R2	R3	R4	Mean
C1	0.102	0.126	0.144	0.099	0.118
C2	0.098	0.112	0.136	0.092	0.110
C3	0.093	0.106	0.126	0.082	0.102

**Figure 2: Performance of Power Tiller in Wet Land at 0-5 Cm Water Level**

Theoretical Field Capacity

It was observed that as water level increases, the speed of operation increases. Maximum field capacity was observed for cage wheel C1 was 0.137 followed by 0.013 and 0.122 for C2 and C3 as shown in (Table 4.1). It was notice that increases in the lug angle, the field capacity decreases but increasing the water level field capacity increases.

Table 4: Theoretical Field Capacity (Ha/H) At Different Lug Angle of Cage Wheel

Treatment/Replication	R1	R2	R3	R4	Mean
C1	0.123	0.139	0.167	0.119	0.137
C2	0.119	0.129	0.157	0.114	0.130
C3	0.109	0.126	0.147	0.106	0.122

Field Efficiency

It is obvious from the (Table 5) that, cage wheel C3 of 60° lug angle has the highest field efficiency 85.73 % followed by C2, 84.12% and C3, 83.13% cage wheel of 45° and 60° lug angle.

Table 5: Filed Efficiency at Different Lug Angle of Cage Wheel

Treatment/Replication	R1	R2	R3	R4	Mean
C1	85.71	88.00	86.22	83.00	85.73
C2	82.35	86.82	86.62	80.70	84.12
C3	85.32	84.12	85.71	77.35	83.13

Fuel Consumption

Due to greater soil wheel interaction of cage wheel C1 lower fuel consumption than other cage wheels. Lowest fuel consumption was 7.77 l/h while maximum was 10.78 l/h at T3 treatment. When cage wheel was operated 0-5 cm water level observed more draft, more sinkage and sticking on lug plate that causes more fuel consumption. The results are shown in Table 6.

Table 6: Fuel Consumption (L/Ha) at Different Lug Angle of Cage Wheel

Treatment/Replication	R1	R2	R3	R4	Mean
C1	10.96	8.89	7.77	9.92	9.39
C2	12.55	10.98	9.75	10.72	11.00
C3	14.62	12.92	10.78	11.36	12.42

Slippage

The speed was observed at load and no load condition in field. Less slippage occurred in R3, 8.19 % for cage wheel C1 and 12.06 %, 11.11% for cage wheel C2 and C3 significantly because of more water easy to cut and move the soil while cage wheel C3 in R1 due to sticking, draft and sinkage, speed is reduced and occurred more slippage 15% . The results are shown in Table 7.

Table 7: Slippage (%) at Different Lug Angle of Cage Wheel

Treatment/Replication	R1	R2	R3	R4	Mean
C1	10.56	9.80	8.19	13.11	10.41
C2	13.66	12.50	12.06	17.48	13.93
C3	15.00	15.21	11.11	15.43	14.18

Sinkage

Sinkage was measured with the help of suitable scale during field operation. More sinkage was observed in cage wheel C2 of 7.4 cm than 7.1, 6.9 of cage wheel C1 and C3 respectively at R1. Less sinkage occurred in R1 of 2.5, 2.7 and 3.2 of cage wheel C1, C3, and C2 respectively, due to more water greater interaction of soil and lug plates as shown in Table 8.

Table 8: Sinkage (Cm) at Different Lug Angle of Cage Wheel

Treatment/Replication	R1	R2	R3	R4	Mean
C1	7.1	4.8	2.5	2	4.10
C2	7.4	5.1	3.2	2.5	4.55
C3	6.9	4.9	2.7	2.3	4.20

Puddling Index

Increase of puddling index in R2 was due to increase in level of puddling because of more soil manipulation by the cage wheel and cultivator. It was observed that maximum puddling index 41 %, 36 % and 28 % of cage wheel C1, C2 and C3 at R2 replication. Higher depth of puddling due to its more weight and action of lug plate that resulted in cutting of soil and mixing with water. The results were shown in Table 9.

Table 9: Puddling Index (%) at Different Lug Angle of Cage Wheel

Treatment/Replication	R1	R2	R3	R4	Mean
C1	32	41	23	21	29.25
C2	24	36	18	13	22.75
C3	21	28	17	14	20.00

Depth of Ploughing

It was observed that depth of ploughing was significantly higher in case cage wheel C3 (13.5cm) and C2 (12.5 cm) than of that C1 (12 cm). When the water level increases depth of ploughing decreases significantly as shown in Table 10.

Table 10: Depth of Ploughing (Cm) at Different Lug Angle of Cage Wheel

Treatment/Replication	R1	R2	R3	R4	Mean
C1	12	9.5	7.5	3.5	8.15
C2	13.5	11	7.5	4.2	9.05
C3	14	12.5	8.5	5.5	10.13

Soil Sticking

Soil sticking is greater problem in lugged wheel in wet land condition. Maximum sticking was occurred in cage wheel C3, 4.6 cm on lug plate than 3.8 cm, 3.2 cm in C2 and C1 in R1. Increasing water level decreasing sticking of soil on lug plate 3.2 cm, 2.3 cm, and 2.0 cm of cage wheel C1 observed as shown in Table 11.

Table 11: Soil Sticking on Lug Plate (Cm) at Different Lug Angle of Cage Wheel

Treatment/Replication	R1	R2	R3	R4	Mean
C1	3.2	2.3	2.0	1.8	2.33
C2	3.8	3.2	2.5	2.2	2.92
C3	4.6	3.5	2.7	2.5	3.32

Different Diameter of Cage Wheels**Time of Operation**

Three different diameter 73 cm, 68 cm and 78 cm diameter of cage wheels were operated in wet land condition. It was observed that cage wheel C1 was highest performance 6.94 h to cover one hectare of field than followed by cage wheel C4 and C5. Cage wheel C4 take the more time to cover due to small diameter of wheel, less speed and more sinkage causes more draft. The results are given in Table 12 below.

Table 12: Time of Operation (h/ha) at Different Diameter of Cage Wheel

Treatment/Replication	R1	R2	R3	R4	Mean
C1	9.80	7.94	6.94	10.10	8.69
C4	12.12	10.31	8.77	14.28	11.37
C5	11.29	9.73	8.28	13.51	10.70

Working Speed

The working speed of power tiller in wet land condition was reduced during increasing of lug angle of cage wheel. It was also observed that as increasing in water level, the working speed increases (Table 13.). The average working speed of cage wheel was found to be 1.82, 1.43 and 1.55 kmph for cage wheel C1, C4 and C5 respectively.

Table 13: Working Speed (Kmph) at Different Diameter of Cage Wheel

Treatment/Replication	R1	R2	R3	R4	Mean
C1(73cm)	1.64	1.86	2.23	1.58	1.82
C4(68cm)	1.29	1.48	1.72	1.23	1.43
C5(78cm)	1.38	1.61	1.89	1.32	1.55

Actual Field Capacity

Cage wheel C1 was higher field capacity than cage wheel C4 and C5 because of greater interaction between soil and lug plate. Cage wheel C4 was lowest because of smaller diameter having more sinkage, and sticking of soil on lug surface but water level increases these are decreased as shown in Table 14.

Table 14: Actual Field Capacity (Ha/H) at Different Water Level

Treatment/Replication	R1	R2	R3	R4	Mean
C1(73cm)	0.102	0.126	0.144	0.099	0.118
C4(68cm)	0.086	0.097	0.114	0.07	0.92
C5(78cm)	0.089	0.123	0.121	0.074	0.102

Theoretical Field Capacity

Theoretically field capacity was observed by theoretically area covered by power tiller implement in wet land condition. Cage wheel C1 gave the higher capacity than other two cage wheel C4 and C5. Due smaller diameter area covering time was more, and also more sinkage and draft. The results are shown in Table 4.12.

Table 15: Theoretical Field Capacity at Different Diameter of Cage Wheel

Treatment/Replication	R1	R2	R3	R4	Mean
C1(73cm)	0.123	0.139	0.167	0.119	0.137
C4(68cm)	0.096	0.111	0.129	0.09	0.106
C5(78cm)	0.104	0.120	0.142	0.096	0.116

Field Efficiency

From the Table 16, cage wheel C1 of diameter 73 cm has highest field efficiency 85.73 % followed by 84.86% and 82.72% for cage wheel C4 and C5 of diameter 68 cm and 78 cm respectively. The field efficiency of cage wheel C4 was lower due to clogging of soil between tynes, sinkage and slippage.

Table 16: Field Efficiency at Different Diameter of Cage Wheel

Treatment/Replication	R1	R2	R3	R4	Mean
C1(73cm)	85.71	88.00	86.22	83.00	85.73
C4(68cm)	85.93	87.38	88.37	77.77	84.86
C5(78cm)	85.09	85.83	85.21	74.74	82.72

Fuel Consumption

The maximum fuel consumption was observed in cage wheel C4, 17.93 l/ha at R1 replication while lowest fuel consumption was 7.77 l/ha of cage wheel C1 at R3. Due to more time of operation and less capacity of C4 cage wheel more fuel consumed it was shown in Table 17.

Table 17: Fuel Consumption (L/Ha) at Different Diameter of Cage Wheel

Treatment/Replication	R1	R2	R3	R4	Mean
C1(73cm)	10.96	8.89	7.77	9.92	9.39
C4(68cm)	17.93	15.28	12.97	15.81	15.57
C5(78cm)	15.91	13.71	11.67	14.66	13.98

Slippage

The slippage observed in 73cm 68 cm and 78cm diameter of cage wheel was presented in Table 18. The maximum slippage was observed in C4, 17.14 % followed by C5 and C1 of 13.15%, and 10.56 % respectively. It was observed that in C1 lowest slippage occurred 8.19% at 10-15 cm depth of water level.

Table 18: Slippage (%) at Different Diameter of Cage Wheel

Treatment/Replication	R1	R2	R3	R4	Mean
C1(73cm)	10.56	9.80	8.19	13.11	10.41
C4(68cm)	17.14	14.63	12.76	18.04	15.64
C5(78cm)	13.15	11.36	9.61	16.20	13.98

Sinkage

The maximum sinkage was (8.10cm) occurred in C4 cage wheel at 0-5 cm water level while it was reduced when water level increased 6.5 cm, 4.10 cm. Lowest sinkage was observed in cage wheel C1, 2.5 cm at 10-15 cm water level as shown in Table 19.

Table 19: Sinkage (Cm) at Different Diameter of Cage Wheel

Treatment/Replication	R1	R2	R3	R4	Mean
C1(73cm)	7.4	4.8	2.5	2	4.10
C4(68cm)	8.10	6.5	4.10	3.5	5.55
C5(78cm)	7.6	6.2	3.7	2.8	5.07

Puddling Index

Maximum puddling index was observed in cage wheel C1 41% at 5-10 cm water level while 21% and 27% for cage wheels C4 and C5 significantly. As increase water level puddling index was reduced to 21%, 18% and 12% significantly for cage wheel C1 as shown in Table 20.

Table 20: Puddling Index (%) at Different Diameter of Cage Wheel

Treatment/Replication	R1	R2	R3	R4	Mean
C1(73cm)	32	41	23	21	29.25
C4(68cm)	21	18	12	9	15.00
C5(78cm)	27	23	19	13	20.50

Depth of Ploughing

Maximum depth of ploughing was observed in C4 cage wheel 15 cm than 12 cm, and 10 cm significantly. Due to more sinkage of C4 cage wheel ploughing depth was more but increasing water level decreased. Lowest ploughing depth was occurred in C1 cage wheel of 5-8 cm at R3 condition than other. The results are shown in Table 21.

Table 21: Depth of Ploughing (Cm) at Different Diameter of Cage Wheel

Treatment/Replication	R1	R2	R3	R4	Mean
C1(73cm)	12.00	9.50	7.5	3.5	8.15
C4(68cm)	15.50	13.20	9.7	6.2	11.15
C5(78cm)	13.5	12.00	8.5	5.5	9.87

Soil Sticking

Soil sticking on lug plate was measured with the help of suitable scale. When the water level was low 0-5 cm the sticking more 6 cm, 3.8 cm and 3, 2 cm of cage wheel C4, C5 and C1. When the standing water level increases sticking reduces on lug surface as shown in Table 22.

Table 22: Soil Sticking on Lug Plate (Cm) at Different Diameter of Cage Wheel

Treatment/Replication	R1	R2	R3	R4	Mean
C1(73cm)	3.2	2.3	2.0	1.8	2.33
C4(68cm)	6.0	4.5	2.9	2.9	4.07
C5(78cm)	3.8	2.9	2.4	2.3	2.85

CONCLUSIONS

In this research it was highlighted that effect of water level on the different lug angle and diameter of cage wheel. It was observed that increasing water level increase the performance of power tiller for all cage wheels. Increasing lug angle decrease the performance where 30° lug angle of cage wheel gave the better performance than cage wheel of angle, 45° and 60°. smaller diameter of cage wheel give the lowest performance in this research.

ACKNOWLEDGEMENTS

This work was supported by the Principal Investigator, Niche Area of Excellence-Farm mechanization in Rainfed Agriculture, Faculty of Agril. Engg. IGKV, Raipur (C.G.)

REFERENCES

1. Kathirvel, K., T.V.Job and R. Manian, (2000). Development and Evaluation of Power tiller operated ladder. Agricultural Mechanization in Asia, Africa and Latin America, 31 (No 1): 22-27.
2. Gupta, J. P. and S. K. Sinha, (2000). Field performance of Bullock Drawn Puddlers. Agricultural
3. Mechanization in Asia, Africa and Latin America, 31 (No 4): 36 – 40.
4. Alvi and Pandya (2001), "Agricultural Statistic at a Glance," Directorate of Economics and Statistics. Ministry of

Agriculture, Govt. of India, 2001.

5. Gupta, J. P. and S. Kumar, 2001. Status of Power Tiller Use in Binar A case Study Nalanda District. *Agricultural Mechanization in Asia, Africa and Latin America*, 32 (No 1): 19-22.
6. Gee-Clough, D. (1992). Improving the performance of agricultural vehicles and implements in wetpaddy fields: final report. AIT research report no. 256, Asian Institute of Technology, Bangkok, Thailand.
7. Salokhe, V. M. and Gee-Clough, D. (1988). Cage wheel blocking in wet clay soil, *Journal of Agricultural Engineering Research*, 39 (4): 277-286.
8. M.S. Abubakar, D. Ahmad, J. Othman, and S. Sulaiman (2009) Present State of Research on Development of a High Clearance Vehicle for Paddy Fields *Research Journal of Agriculture and Biological Sciences*, 5(4): 489-497,
9. Datta, P. and T.P. Ojha, 1970. Design of Wheel Parameters for Puddled Soils. *Journal of Agricultural Engineering*, 7(3): 60-65.
10. Jayasundera, L., 1980. Study of factors affecting the design of lugged cage wheels in paddy soils. M. Eng. Thesis No. AE-80-15, Asian Institutes of Technology.